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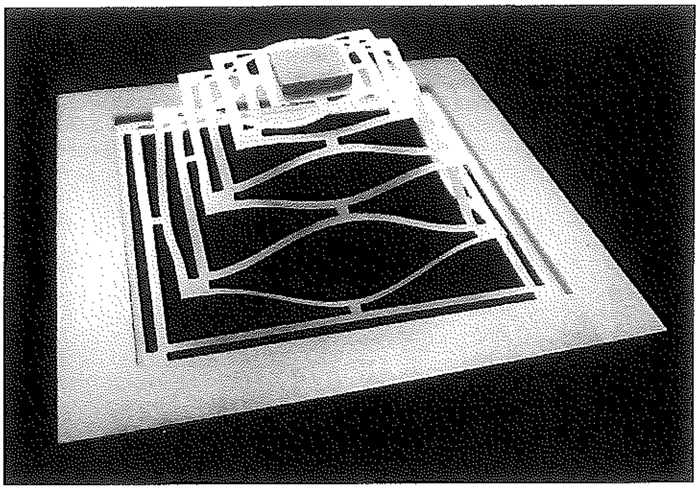
Kirigami graphene makes tiny devices

Graphene fashioned into resilient and movable parts

After discovering that graphene sheets bend and crumple just like paper, researchers in the US hit upon the idea of using the material in the ancient Japanese art of paper-folding to make three-dimensional structures. Employing kirigami, a variant of origami that includes cutting, the team created graphene hinges and springs. The team claims that the technique could be used to produce super-soft electronics and sensor devices.

Graphene, the one atom thick two-dimensional carbon allotrope, which won its discoverers the 2010 physics Nobel prize, has made headlines recently as it has made its way into everything from light bulbs to water purification technologies (see *Chemistry World*, July 2015, p42). Prized for its superior conductivity and flexibility intensive research is under way to employ it inflexible electronics to produce bendy displays and LEDs.

While investigating the mechanical properties of graphene, researchers from



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Graphene can be used to create kirigami springs that maintain their conductivity when stretched

Cornell University, US, found that their graphene sheets were stiff like crumpled paper. 'We were quite surprised by this,' says Paul McEuen, who led the team. They had expected graphene to be far more flexible. 'We could take atomic scale predictions of what [the stiffness] should be, and the answer we got was very different from what we measured.'

Exploiting its paper-like nature, the team used principles from kirigami to make microscale spring and hinges. 'It was really just curiosity and fun,' McEuen says. 'We were just talking about what to do with an atomically thin piece of paper and the obvious idea of doing these kinds of paper arts came up.' The researchers first patterned the graphene and then removed the unwanted pieces using an oxygen plasma.

They found that their kirigami creations held their shape: despite the graphene hinge being only one atom thick, it was still intact after being opened and closed 10,000 times. Similarly, the extension of the graphene spring didn't affect its conductive abilities. The applications of these findings are potentially far-reaching. The researchers point to super-soft electronics to monitor cells as one interesting area. 'Let's say you want to record the firing of a neuron,' says McEuen. 'We're trying experiments right now to put a kirigami graphene structure over a neuron and see if we can do a better job of sensing its firing – but that's work in progress.'

'This is a remarkable piece of work that opens new avenues for nano-electromechanical systems and also adds to our understanding of graphene membranes,' says materials scientist Jannik Meyer from the University of Vienna, Austria. However, he stresses the need for further research: 'I look forward to seeing whether these devices can also operate outside of the liquid solution, which is important for realising their potential.' *Ida Emilie Steinmark*

Reference

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Battery buffer takes the strain

Material for safer and longer lasting batteries

Researchers in China and the US have developed a layered oxide that shrinks when ions are intercalated into it, with the hope of buffering the volume expansion seen in common electrode materials.

Layered oxide materials are very stable, have large interstitial spaces, and often undergo a volume change, or "strain effect", when they incorporate ions into their structure. This volume change, however, is detrimental to the electrode's performance and safety within a battery. So-called zero-strain materials, where no volume change is seen, are ideal electrode materials. However, these are rare and most layered oxides exhibit a positive strain effect.

Many layered oxides have the formula A_xMO_2, and consist of stacked $(MO_2)_n$ sheets with edge-sharing MO_6 octahedra, in between which alkali metal atoms are located at octahedral, tetrahedral, and prismatic sites. Now, Xuefeng Wang at the Chinese Academy of Sciences and co-workers have synthesised $Na_{0.5}NbO_2$, a layered oxide where the NbO_6 clusters are edge-sharing trigonal prisms rather than octahedra, so the sodium and niobium ions sit in opposite coordination environments to what would be expected.

$Na_{0.5}NbO_2$ is a rare negative-strain material with high stability, a long cycling life and an impressive rate performance. As Jang Wook Choi, a researcher in the Energy Nanomaterials Group at the Korea Advanced Institute of Science and Technology explains. 'This is opposite to other cases or common sense, as the volume shrinks even after you put something inside the structure.' The negative volume effect appears to be a result of enhanced interlayer Na–O interactions and weakened Nb–Nb and Nb–O bonding on sodium intercalation.

Wang and colleagues evaluated $Na_{0.5}NbO_2$ both as an independent electrode material, and as a buffer in composite electrodes with positive-strain materials, in which it counteracts the volume expansion caused by a positive strain effect. The material had a more significant volume effect than other volume buffer materials, as well as being electrically conductive and compatible with electrolytes at the required voltage.

'The limitation of our system is high cost of niobium and the difficult synthesis,' says Wang. 'But we think these results will influence thinking about how to design electrodes for rechargeable batteries.' *Laura Fisher*

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